CLERMONT VISITOR CENTER
PROTOTYPE ENVIRONMENTAL CONTROL PROJECT REPORT

27 December 1998

Prepared for:
The New York State Bureau of Historic Sites
Peebles Island, PO Box 219, Waterford, NY 12188
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The issues addressed in this report concern the special requirements of museum and library/archive environments, and are presented exclusively in an effort to prolong the life of the institution's collection. In addition to these, other concerns affecting design and operating decisions will need to be considered by the architect, engineer and other professionals responsible for designing and operating the facilities. The issues herein may need to be subordinated to those other concerns.

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The observations and comments in this report are intended for the projects that are the specific scope of this report. They are based on current research and understanding of the issues as they relate to these projects in a particular context, with needs, opportunities and limitations often unique to the project. Using specific improvements suggested in this report on other projects can put a collection and building at risk from inapplicable situations that may seem the same to the uninformed. As part of the scope of this project, Garrison/Lull will assist the Bureau in the preparation of a findings article or paper covering general information and issues appropriate for publication and general use.

EXECUTIVE SUMMARY

The collections at the Clermont Visitor Center provide an important history, information and cultural resource. However, the building has several shortcomings as a good conservation environment. Among these are low humidity in winter, high humidity in summer, high temperature in summer, moderate particulate and gaseous contamination, and expected problems with humidity tolerance of the building envelope in winter. These problems indicate a collection environment deficient in providing the most reasonable life for the collection. However, the efforts and expenses to create and maintain a first-class environment for the Visitor Center collections are too high considering the number of such situations throughout the State.

PROTOTYPE PROJECT. Modest measures to mitigate some of these problems have been taken through the implementation of a prototype renovation project. This has made certain modifications to the building, primarily to the existing heating system, to offer improvements to conditions within the limitations of temperature and humidity control of heating and ventilation. To prevent introducing problems from the additional outside air, the system has an aggressive filtration system. As a prototype project these renovations and improvements are those that are the least predictable in performance while also having the widest promise for use at other Bureau sites and similar sites in similar climates.

PERFORMANCE. The monitoring data shows the renovated Visitor Center environment is effective in moderating the effects of the outside environment. Moreover, close inspection of the data suggests the system is clearly reducing the range of humidity in the space by careful articulation of the fan, heating and outside air.

APPLICABILITY TO OTHER SITES. The prototype is applicable to other sites where the wide range in temperatures required for such a treatment can be supported. As proved by the Clermont experience, the expectations for comfortable temperatures, particularly in winter, must be reconciled with the expected results of such a renovation. The project can only be as successful as the tolerance for temperature variations that are essential for such a system to work.

INTRODUCTION AND SCOPE

This report was commissioned by the New York State Bureau of Historic Sites under a Preservation Technology and Training Grant. It is intended to assess the Clermont Visitor Center prototype project as implemented from 1995 through 1998.

Primary participants in the project included:

Ms. Heidi Miksch, Conservator, Peebles Island;
Mr. Bruce Naramore, Historic Site Manager, Clermont;
Mr. Robert Engle, Curator of Collections, Clermont;
Mr. Bob Herbst, Engineer, Taconic Region;

Mr. William P. Lull, Garrison/Lull Inc;
Mr. Gerald Slaton, Principal in Charge, Slaton Design Services.

The Peebles Island staff provide multi-disciplinary support and resources pertaining to historic collections and structures to all Bureau sites in all regions. The regional engineers oversee capital projects, including mechanical environmental systems, at sites within their region. Site personnel are responsible for the administration and day-to-day operations at their site.

Garrison/Lull programmed the improvements project, and provided the prototype control panel. As a subcontractor to Garrison/Lull, Slaton Design Services designed the prototype project, providing the drawings and specifications for the renovation done by State crews.

The project manager, Ms. Heidi Miksch, participated in all the on-site meetings, and, with the other conservators at the Bureau, has provided information and investigations in support of the project.

SCOPE. Garrison/Lull is serving as a consultant to the New York State Bureau of Historic Sites to help in defining conservation environment needs to promote conservation of the collection, and to plan an effective conservation environment for the collection through the site buildings and building systems. The comments offered by Garrison/Lull are based on established and published principles in building physics, construction technology, informal and formal research, and on observations and experience at many other museums, libraries and archives. Garrison/Lull is not a licensed engineer or architect, is not a construction official, and performs no architectural, engineering or building construction services including but not limited to preparing actual design drawings, specifications and calculations, or identifying and resolving issues of public health and safety.

This report is prepared specifically for use by the New York State Bureau of Historic Sites and their consultants and contractors for this particular project. Garrison/Lull reports are based on current research and understanding of the issues as they relate to a particular project in a particular context, with needs, opportunities and limitations often unique to that project. Using these comments on another project may put a collection or structure at risk from inapplicable situations that may seem the same to the uninformed.

Garrison/Lull services have not addressed the specific condition or sensitivities of the collection and the services are in no way a substitute for the services of trained conservators. The comments offered here do not include specific issues relating to handing, exhibition and storage of the collection, nor to specific functional and conservation merits of furnishings, storage cabinets and exhibition cases.

BACKGROUND

The following section discusses the project background as the basis for the prototype project implementation.

SITE SELECTION

A preliminary phase to the programming work for this project was selection of the project sites. A selection was made from the potential sites that were anticipated in the grant proposal using criteria to represent conditions typical for the Bureau and, as possible, other similar sites nationwide. This identified three (3) sites for further study and development of environmental renovation programs. (This work is detailed in the 21 December 1995 Garrison/Lull program report.) From these, a single site was identified for the prototype project.

The Clermont Visitor Center was chosen because it represented historic frame construction and no cooling. With low-capitalization for the HVAC systems it was similar to many of the Bureau sites. With a forced-air furnace it also represented a very typical minimum HVAC treatment for many smaller historic sites. Although it did not have hygrothermograph data at that time, data collection began in January 1995 and will continue into the summer to establish a winter-summer baseline for the project. Clermont was identified as the best candidate for the prototype treatment since there was little desire to capitalize the site with a conventional HVAC system, yet environmental improvements were indicated. The site offered a straightforward opportunity to try low-cost simple prototype improvements, consistent with the expected project budget.

For a full discussion of the observations, evaluations and issues for the Clermont Visitor Center site, see the 21 December 1995 Garrison/Lull program report.

COLLECTIONS AND PRIORITIES

The Clermont Visitor Center has an 1890's Opera Bus (carriage), and display of glass, ceramics, metals, plaster, terra cotta, wooden objects, basketry, oil-based non-drying clay sculpture, paper, textiles and inorganic archeological material. Most of these collections are original artifacts, and while a few reproductions are used, extending the life of these also has a high value due to the high cost to replace them.

ARCHITECTURAL/GENERAL

The Visitor Center is one of several buildings at the Clermont site, located in a rural area near the Hudson River in the Taconic Region. The Visitor Center is a modern renovation of a carriage barn built late 1800's. It has a main floor with an attic above, and a concrete floor crawl space below. Except for the concrete subfloor in the crawl space the building is wood frame construction. The exterior is painted. The interior of the first floor reception and exhibit areas has refinished original wood and modern drywall, and a wood floor. The interior of the stable area is refinished original wood, with a brick paver floor. The interior of the attic is the exposed wood structure.

The first floor is divided between the stable (or horse stalls) area and the reception and exhibit areas. The stable area is not served by the heating system and is interpreted as its original function. The attic, although large with good clear height, is not necessarily suitable for storage or occupied uses since it does not appear to have a high structural capacity.

The space currently reported in the building is as follows, in square feet.

	Collection Areas	Other Areas	Totals
Clermont Visitor Center			
Heated Areas:			1,802
Display Area	1,573		
Restrooms, Supply Room		229	
Unheated Areas:			
Stables	970		
Second Floor		2,772	
Other Totals:			
First Floor			2,772

Modern glass storefront windows and doors have been installed behind the original north and south doors. The other glazing, although modern, is in the original locations. The ceiling of the first floor has been insulated with loose fiberglass "blowing" wool. If a vapor barrier was used, it is now allowing debris to filter down to the first floor.

HVAC/MECHANICAL

Prior to the prototype renovations, the Visitor Center was served by a residential forced-air furnace with a residential on-off thermostat. Return air is drawn in at the foot level of the reception desk, blown through the furnace heat exchanger, and then down into an craw space supply air system, coming to the first floor through a series of registers at the perimeter of the main room. Since the stables have a different floor structure with no crawl space that area has no supply air and tends to be cold in winter.

EVALUATION. The key desirable features of HVAC systems serving collection spaces are: a) Constant Volume Ducted Air Distribution with Forced Air Heating; b) Cooling; c) Positive Dehumidification (usually cooling with reheat capability); d) Humidification, preferably with clean steam; e) Particulate Control to 85-95% ASHRAE Dust Spot; and, f) Gaseous Contamination Control, if warranted.

The Visitor Center provides only (a), which while limited in scope, is the basis for the other features.

GASEOUS CONTAMINATION

PURAFIL CORROSION CLASSIFICATION COUPONS. This test, used to monitor site conditions, is based on the gaseous corrosion "coupon test" developed by the Instrument Society of America (ISA). However, the Purafil test is proprietary and is designed to test for museum and library pollutant levels. Coupons were provided in February 1995 for use at the project site to test the exposure of collections to corrosive gases that will typically react with elemental silver, the test material. One additional coupon was provided at no additional charge for a reproducibility test. The following areas were tested:

- inside case with tarnish,
- inside another case with no tarnish,
- in ambient air around cases,
- inside case with tarnish (reproducibility test).

The coupons were exposed for one month and then returned for lab analysis. The test results were as follows:

CORROSION COUPON TEST RESULTS

	---- CORROSION ----				EXPOSURE		
COUPON LOCATION	AgCl	Ag2S	Ag-?	Total	Season	Days	Comments:
Case w/Tarnish	0	369	750	1119	Spring	29	Left back corner
Case w/o Tarnish	0	99	162	261	Spring	29	Fulton case
Room Ambient	45	84	522	651	Spring	29	Opera Bus shelf
Case w/Tarnish	0	498	660	1158	Spring	29	Right front

All values in Angstroms of corrosion normalized to a 90-day exposure.

Levels below 100 Angstroms of total corrosion are typical of spaces with effective gas-phase filtration, or with a benign ambient environment; levels between 100 and 200 Angstroms show the need to consider some level of gas-phase control; levels above 200 Angstroms show the need to provide some level of control; levels above 300 Angstroms show the need to provide an aggressive level of control.

Each of these tests show high levels of corrosion, indicating the need for better gaseous contamination control.

MAINTENANCE

There are no formal building maintenance/operation staff assigned to the building, or the main house at Clermont. Interior cleaning of the Visitor Center is done by guide staff; restrooms are maintained by the grounds maintenance staff; furnace filters and collection displays are maintained by the museum technician for the main house. There are no outside service contracts on the Clermont Visitor Center building systems. Renovation or repair projects are handled by the regional restoration crew or outside contractors. The regional engineering offices oversee capital projects.

COLLECTION PROBLEMS

The following problems directly relate to the effect of the environment on the collection, or to the building systems, ultimately posing a threat to the collection.

- High temperatures in hot summer weather;
- Low winter humidity;
- Particulate contamination and debris from ceiling;
- Silver tarnish;
- High light levels on some objects;
- Contrast glare and veiling reflections on some display cases and objects.

NSERVATION ENVIRONMENT RENOVATION PROGRAM

response to the problems and observations, and working with the Bureau aff, a renovation program was developed to implement a prototype project at Visitor Center. The efforts and expenses to create and maintain a first-ass environment are too high considering the number of such situations roughout the State. Instead, modest measures to mitigate some of these oblems were planned through the implementation of a prototype renovation oject.

s was to make certain modifications to the building, primarily to the sting heating system, to offer improvements to conditions within the itations of temperature and humidity control of heating and ventilation. To igate problems from the additional outside air, the system has an aggressive tration system. The project was to provide humidity-controlled heating and tilation, fine particulate control, good system operation and reliability, control of gaseous pollutants.

a prototype project these renovations and improvements are those that are least predictable in performance while also having the widest promise for at other Bureau sites and similar sites in similar climates.

TROL FUNCTION MATRICES. The following matrices represent the control logic eloped for the prototype project. In each matrix the measured conditions represented on the sides of the matrix with the resulting control action in appropriate matrix cell.

DEW POINT VENTILATION CONTROL LOGIC MATRIX

FAN CONTROL: Space Relative Humidity Exceeds Set Point = FAN ON
Space Temperature Exceeds Set Point = FAN ON

OUTSIDE AIR DAMPER CONTROL:

DEW POINT	TEMPERATURE COMPARISON: Outside > Inside	Inside > Outside
Outside Exceeds Inside	DAMPER CLOSED	DAMPER CLOSED
Inside Exceeds Outside	DAMPER OPEN	DAMPER OPEN

OVERRIDE: Outside Temperature < Space Minimum Set Point = DAMPER CLOSED

HUMIDITY-CONTROLLED HEATING LOGIC MATRIX

FAN CONTROL: Heat On = FAN ON

SPACE RELATIVE HUMIDITY	SPACE TEMPERATURE: Below Minimum Temperature	Between Maximum and Minimum	Above Maximum Temperature
Below Set Point	HEAT ON	HEAT OFF	HEAT OFF
Above Set Point	HEAT ON	HEAT ON	HEAT OFF

Set Points:

Space Relative Humidity	40% RH Mimimum, 50% RH Maximum
Minimum Temperature	40 degF, Revised to 62 degF for State requirements
Maximum Temperature	75 degF

PROTOTYPE PROJECT DESIGN AND CONSTRUCTION

At the Bureau's option, Garrison/Lull secured the services of the selected engineer, Slaton Design Services (SDS), to consult on the prototype treatment project and check the appropriate treatments selected for the site.

The design for the prototype project was discussed at the 19 July 1995 meeting, and included visiting the prototype site and discussing the prototype project. This meeting included selected Bureau staff, and the design engineer selected. Refinements to the treatments and approach were made. Where possible treatments were selected that Bureau crews might complete without the need for bidding or contract administration services. The approach selected was developed into a set of drawings and specifications by SDS.

As designed, all work was to be done by the Bureau crews, although sub-contracting to some limited trades, such as for sheetmetal, was expected. So they might have a minimum historical impact on the building, the Bureau was to design and fabricate the new louvers to the free area requirements provided by the design engineer. The Bureau was to procure all the equipment and materials to complete the engineer's design, with the exception of the control panel and sensors - these were to be provided by Garrison/Lull. Garrison/Lull provided the programming of the computer control system for the logic control sequences selected for the treatments at the site.

The renovation was substantially complete in April 1998, with the main temperature/humidity control components operative.

PROTOTYPE SYSTEM DESCRIPTION

The prototype system installed at the Visitor Center is designed to moderate humidity and temperature extremes to reduce the severity of the environmental exposure to the collections on display. It uses the existing furnace and supply ductwork with additional elements to moderate conditions within a broad temperature range for more stable humidity, including "humidity-controlled heating" and humidity-controlled ventilation.

(For specific information and instructions on the operation of the system and detailed equipment schematics consult the separate *Prototype HVAC Controls Operating Instructions for the Clermont Visitor Center* updated as of this date.)

The system installed consists of the following components, as shown in Diagram 1:

1. MAIN AIR SYSTEM. This consists of the original furnace and supply ducts, as well as a new fan system in the attic that has filters and new ducts connected to a new outside air louver on the west side. To control unwanted air flows the outside air and return air are each controlled with motorized low-leakage dampers.

2. SPACE EXHAUST. To complement the main air system's use of outside air, a new exhaust system in the attic draws air through the hay loft opening in the horse stall area and exhausts it through new louvers on the east side.

3. ATTIC EXHAUST. Separate from the other systems, an attic exhaust system exhausts air from the attic through the new east louver when the attic is too warm, drawing air through the attic and the open area in the new louver on the west.

4. CONTROL PANEL. A special Control Panel controls the main air system (1.) and space exhaust (2.).

The attic exhaust is controlled by a separate attic thermostat and not the Control Panel.

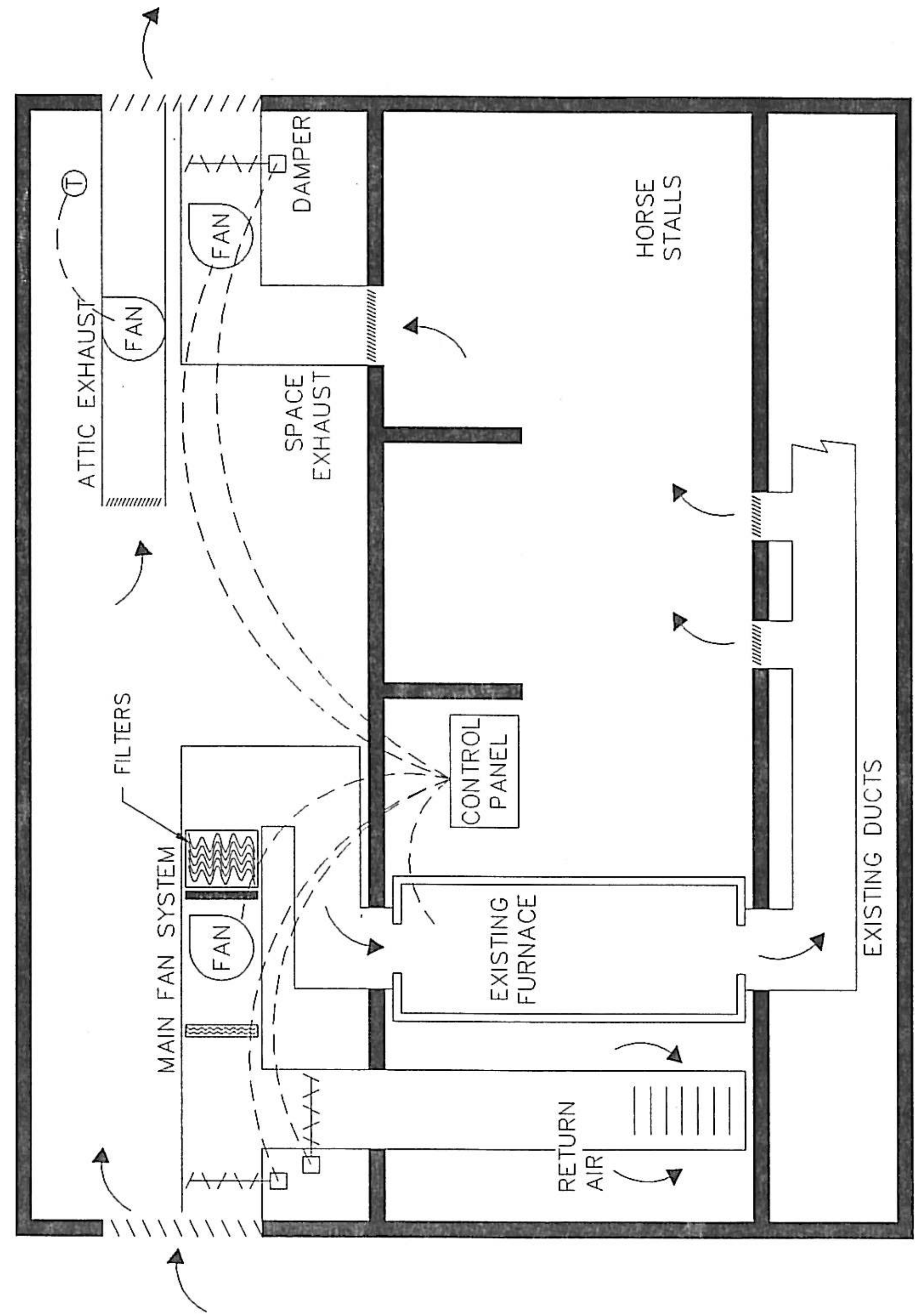
HEATING. The system has the same heating capability as before the renovations, using the same oil-fired furnace.

COOLING. The system has no cooling, per se, but does have the ability to circulate the air, and bring in outside air for ventilation when the air is favorable.

HUMIDIFICATION & DEHUMIDIFICATION. The system has neither of these, per se, but by controlling the heating in a large deadband, and using heating when the humidity is high, moderation of humidity is possible.

PARTICULATE FILTRATION. The new fan system has a 2-inch 30% ASHRAE Dust Spot efficiency prefilter, 12-inch 30% ASHRAE Dust Spot efficiency final filter, and a 1-inch carbon bypass filter panel. These reduce the amount of particulates drawn in through the outside air and recirculated through the air system. The carbon panel filter is intended to take the edge off the ozone drawn in with the outside air.

DIAGRAM 1


DAMPER
HORSE STALLS
FAN
T
FAN
ATTIC EXHAUST
SPACE EXHAUST
FILTERS
CONTROL PANEL
MAIN FAN SYSTEM
FAN
EXISTING FURNACE
EXISTING DUCTS
RETURN AIR

PROTOTYPE CONTROL PANEL

The prototype system is controlled by a special prototype Control Panel, providing four modes of operation:

0 - Fan Off, Outside Air Closed, Exhaust Fan Off, Heat Off; the system is "off."

1 - Fan On; the main air system recirculates air.

2 - Outside Air Open/Exhaust Fan On; the main air system ventilates with outside air by opening the outside air damper and closing the return damper; and the space exhaust system is on with its damper open.

3 - Heat On; the system heats with the existing furnace.

In modes (2) and (3) the fan, mode (1), also operates.

CONTROL LOGIC. The following logic is used by the Control Panel:

- When interior humidity is above 50% RH then the fan (1) is on to suppress mold growth (and increase comfort).
- When interior temperature is above 75 degF then the fan (1) is on to assure even temperatures (and increase comfort).
- When interior humidity is above 50% RH and the space temperature is below 75 degF then the heat (3) is on to reduce the relative humidity by heating the air.
- When the interior humidity is below 40% RH and the exterior humidity is higher (when corrected to interior temperature) then the outside air (2) is opened and the fan (1) is on.
- When the interior humidity is above 50% RH and the exterior humidity is lower (when corrected to interior temperature) then the outside air (2) is opened and the fan (1) is on.
- When the interior temperature falls below 62 then the heat (3) is on along with the fan (1) to keep the building from freezing.

"Correction" of the outside air to inside conditions includes a psychrometric calculation using inside and outside temperature and relative humidity.

There is a separate "backup thermostat" located just above the Control Panel that will make the "heat" contact regardless of panel operation.

POWER. Power to the Control Panel may be interrupted as necessary using the on/off toggle switch at the top right corner. Whenever the power is turned on, the Panel automatically starts the control program. With the power off, the Control Panel will be inoperative. The only operational controls will be the low-level backup thermostat, and the thermostat for the fan exhausting the attic.

STATUS LIGHTS. Pilot lights on and in the panel indicate power status. Visible through a hole in the panel, are lights on the "ST I/O Module:" an "Interrupt" light on the "ST I/O Module" blinks every second, red "Sampling" lights flash in sequence 10 times every 100 seconds, three green status lights indicate if the FAN, OUTSIDE AIR, and HEAT are on. These are the three items controlled by the Control Panel.

PANEL ALARM. The Control Panel has an alarm that is triggered by low space temperature. While there is a separate backup thermostat to be sure the heat comes on at low temperatures, the alarm indicates the heating system should be checked.

LAPTOP COMPUTER FOR CONTROL PANEL. As part of the project, Garrison/Lull provided a laptop computer to interface with the Control Panel. It can be connected to the Panel as needed, to restarting the program (although this is automatic at power-up), modifying program settings (such as temperature/humidity set points), and loading a new program.

CONTROL PANEL REPAIR. The Control Panel schematic is included in the project operating instructions manual and is also affixed inside the Control Panel cover. Most components can be replaced as noted on the schematic. The only non-standard items are the "Blue Earth Micro" (BEM) microprocessor and its "Standard I/O" module. A different BEM model may not operate as the one installed in the panel and may require a new program.

DECOMMISSIONING THE CONTROL PANEL. The intelligent use of outside air and heating to control humidity require the Control Panel. The prototype system can be operated with thermostats instead if these features are not required, or if the Control Panel fails and cannot be repaired.

ATTIC VENTILATION

The attic ventilation system is not controlled by the Control Panel; instead, a thermostat near the fan motor starter calls for operation when the temperature is above 80 degf (adjustable). When in operation, the attic exhaust damper opens and the exhaust fan operates. Makeup air is drawn in the open portion of the damper on the west side.

DATA LOGGERS

The operation and performance of the prototype installation is monitored by the Bureau with their two (2) four-channel ACR SR-2 data loggers, installed as follows:

Logger 1 (inside the Control Panel)
- (Channel 0 - Internal Temperature (inside Control Panel))
- Channel 1 - Fan (on/off)
- Channel 2 - Outside Air/Exhaust (on/off)
- Channel 3 - Heat (on/off)

Logger 2 (near the utility room door)
- Channel 0 - Internal Temperature (at logger near door to utility room)
- Channel 1 - Internal Humidity (at logger near door to utility room)
- Channel 2 - External Temperature (at external sensor & enclosure)
- Channel 3 - External Humidity (at external sensor & enclosure)

The loggers perform monitoring only, and are not necessary for the Control Panel to function.

DOWNLOADING DATA. The logger data has been downloaded by the Bureau staff using a separate computer and software. If necessary, the laptop computer provided with the system can also be used to do this with specially-prepared 720MB diskettes.

PROTOTYPE SYSTEM PERFORMANCE

The renovated Visitor Center is effective in moderating the effects of outside temperature/humidity conditions on the environment within.

MODERATION OF OUTSIDE CONDITIONS (CHART 1A/1B). Chart 1A shows the outside temperature and humidity conditions for the logged data periods while Chart 1B shows the interior conditions for the same periods. Since there was no control space for comparison, and some moderation is expected for any enclosed space, the effects of the prototype system require closer analysis.

TEMPERATURE/HUMIDITY CONTROL OF HEATING FOR "DEHUMIDIFICATION" (CHART 2). This is suggested in Chart 2, where heat operation, indicated by the up-notches at the bottom, is called for while the space humidity (the lower graph line) is above 50% RH, but inhibited whenever the space temperature (the upper graph line) is above the 75 degF maximum.

TEMPERATURE/HUMIDITY CONTROL OF OUTSIDE AIR FOR "HUMIDIFICATION" (CHART 3). Chart 3 shows the more-stable inside and less-stable outside temperatures above, and similar plots for humidity below; at the bottom is the open/closed control notches of the outside air.

At the beginning of the chart, while the outside humidity and temperature are above space set point conditions, the outside air is closed. It first opens when the space humidity is below the 40% set point, and outside humidity is higher, thus helping keep the humidity up. It then cycles to keep the humidity at 40%, as shown by the cycling of the outside air and associated cycling of the space humidity as the 40% RH set point is reached. Finally, the cool, moist night conditions raise the space humidity above 40% and the outside air closes until the next day. This resumes the next morning, and continues when the outside air humidity is *apparently* too low; however, those outside air conditions at mid-day (112 degF/20% RH) indicate air at 82 grains/pound, which, when brought inside to 78 degF, is air at 57% RH. Thus, the control program calculates the effect of the air once brought inside and continues to use it to humidify the space. This illustrates the need for the correction of the raw outside air readings in determining the use of outside air.

Due to compromises imposed by operation of the backup thermostat for comfort conditions, all portions of the operating period do not exhibit these control signatures.

LIMITATION IN PERFORMANCE

Since it has no humidification nor dehumidification elements per se, the extent to which the prototype system can moderate humidity is the extent to which the temperature in the space can be allowed to vary between the minimum of 62 degF and maximum of 75 degF. Conditions would be improved if the temperature were allowed to go down to 55 degF or lower; similarly, conditions are poorer if the minimum temperature (or backup thermostat) are set closer to 75 degF.

CONCLUSION

Although the project has not operated yet for a full year, the data clearly show that the prototype system is capable of articulating the fan, heating and outside air in such a manner so as to reduce the range of humidity conditions within the treated space.

CHART 1A - OUTSIDE CONDITIONS

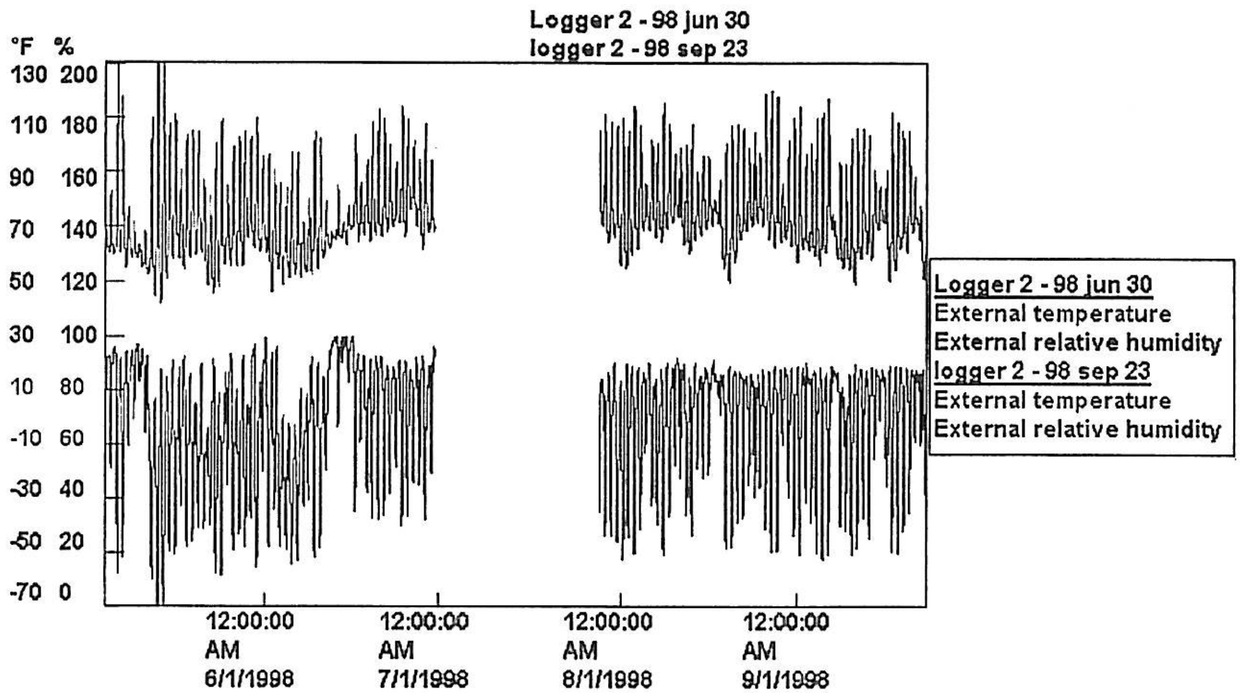


CHART 1B - INSIDE CONDITIONS

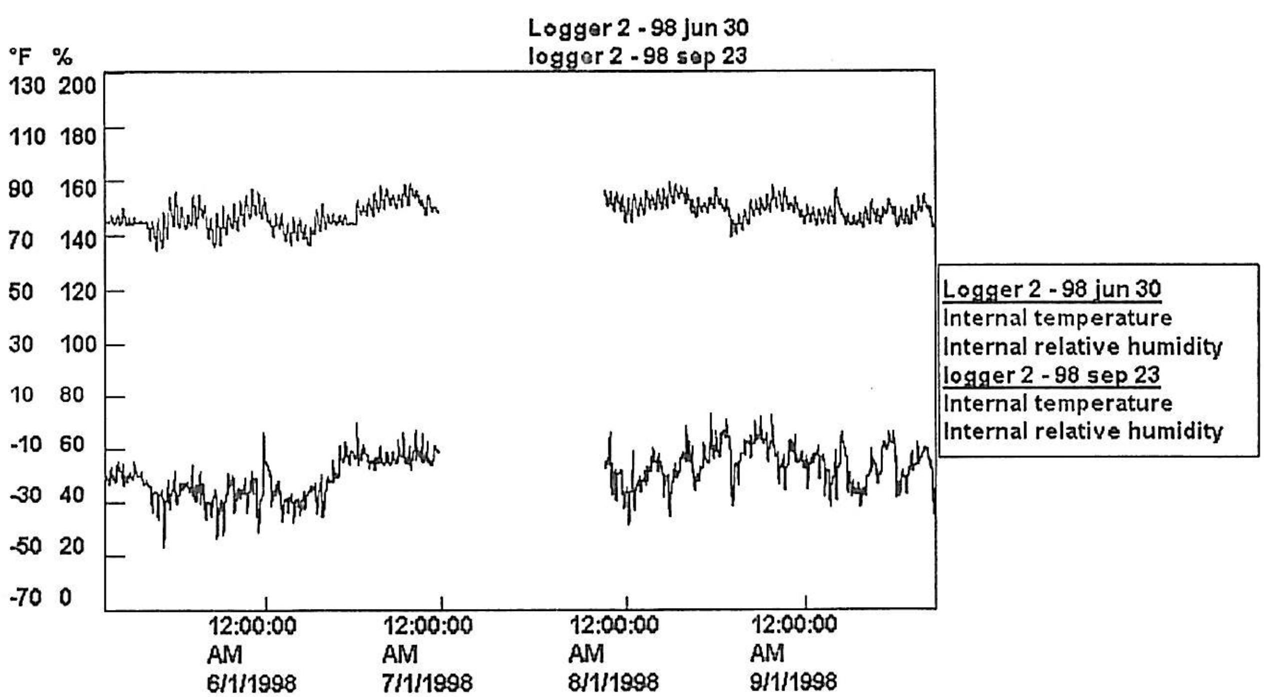


CHART 2 - HEATING FOR "DEHUMIDIFICATION"

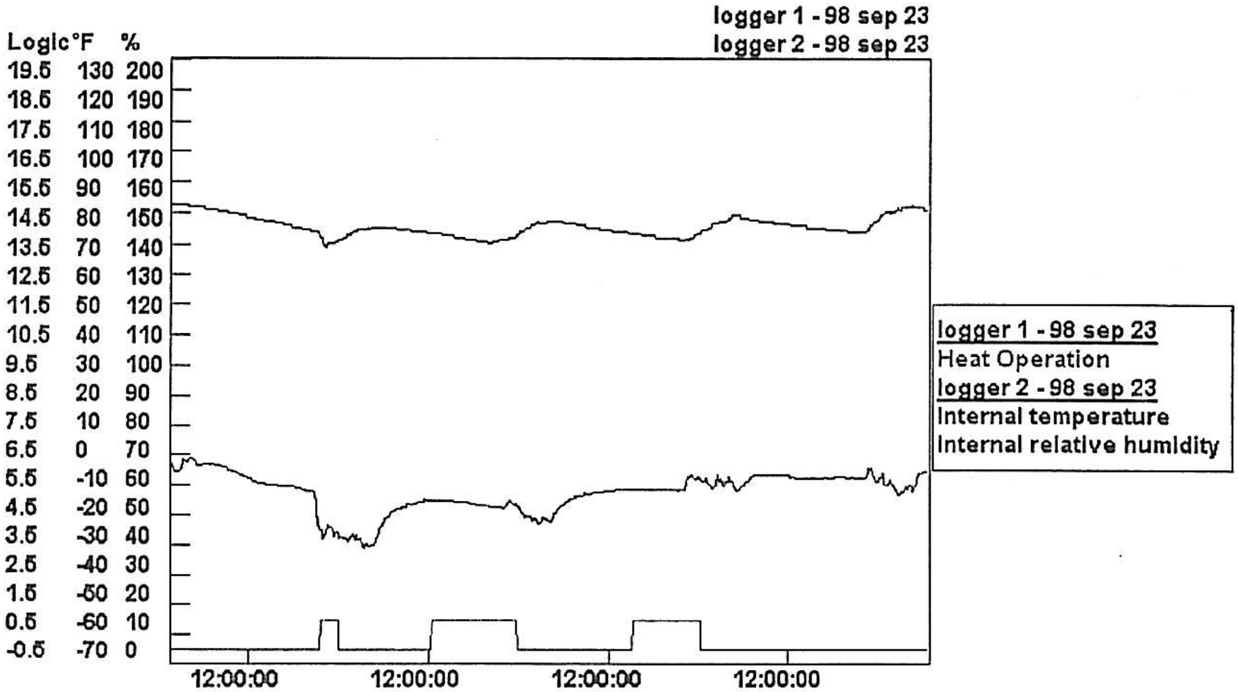
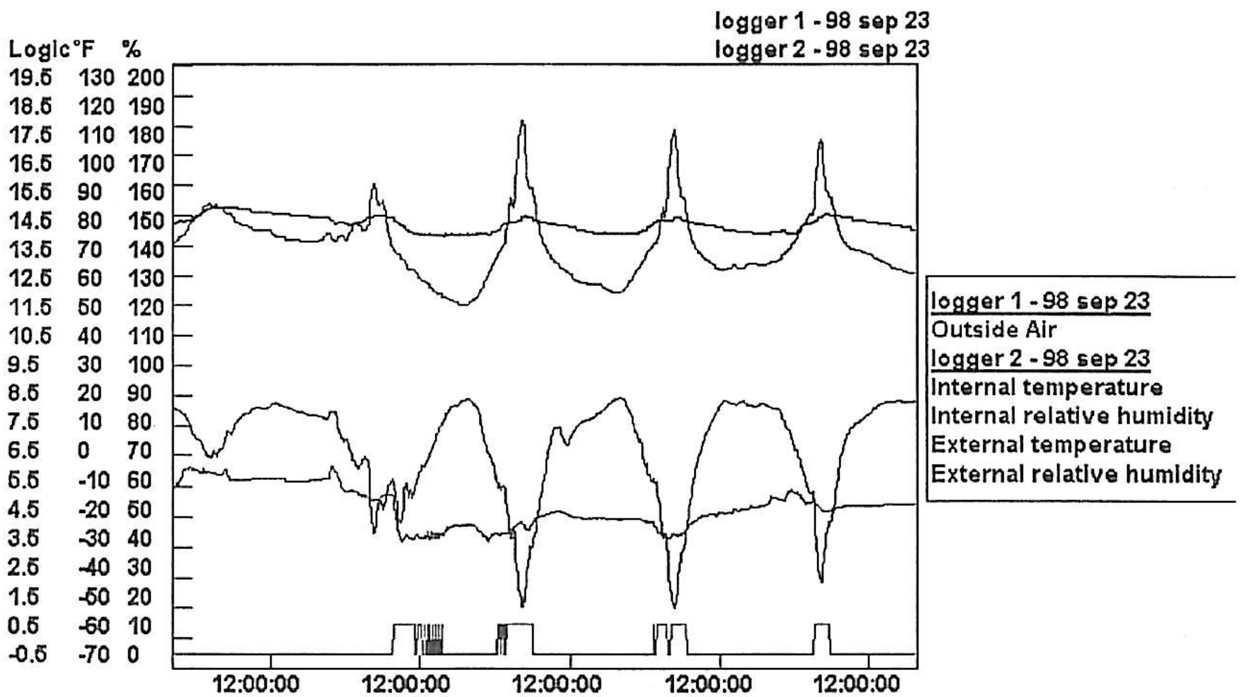


CHART 3 - OUTSIDE AIR FOR "HUMIDIFICATION"



APPENDIX

CONTROL PANEL PROGRAM LISTING

```
1       REM Heat/OA/Fan Controller Program 1.5 - 4/2/98 - 9:00a
20      XBY(0FEE0H) = 4
30      TCON = TCON .AND. 0F7H
100     RHmin = 40 : RHmax = 50 : Tmin = 62 : Tmax = 75
110     ENTHALPY=1
120     FIRST=1
130     XRO=0 : LC=0 : CTRL1=255 : CTRL3=255
140     PORT1=CTRL1
150     DIM A(20)
199     ONEX1 500
200     IDLE
210     GOTO 200
500     REM MAIN PROGRAM LOOP
503     IF (FIRST=1) THEN A=GET : FIRST=0
505     A = GET : IF A <> 0 THEN GOSUB 1000
510     LC = LC + 1
515     IF LC < 100 THEN 599 ELSE LC = 0
520     GOSUB 700
599     ONEX1 500 : RETI
700     REM OPERATIONAL SEQUENCE
710     GOSUB 2000
720     IF (ENTHALPY=1) THEN GOSUB 3000
730     GOSUB 4000
740     PORT1=CTRL1
741     PORT3=CTRL3
799     RETURN
1000    REM Console Support/Display Subroutine
1001    PRINT:PRINT "***** CONSOLE/IMMEDIATE MODE ACTIVE *****"
1002    PRINT "DO NOT DISCONNECT CONSOLE UNTIL PROMPTED!!",CHR$(7)
1003    GOSUB 5000
1004    GOSUB 6000
1009    TEST=0
1010    PRINT : PRINT
1011    PRINT "SETPOINTS --1-- --2--       --3-- --4--"
1012    PRINT "     Temp: Min   Max   RH: Min   Max"
1015    PRINT USING(##.#),SPC(10),Tmin,Tmax, SPC(5),RHmin,RHmax
1016    PRINT
1020    PRINT "   INPUTS --5-- --6--       --7-- --8-- --*--"
1021    PRINT "         IA: degF  % RH   OA: degF  % RH  % RH"
1022    PRINT USING(##.#),SPC(10),Tin,RHin, SPC(5),Tx,RHout,RHth
1023    PRINT "* OA RH Corrected to IA Temp"
1029    IF ENTHALPY=1 THEN P. "9: ENTHALPY Mode - using %RH* for OA"
1030    IF ENTHALPY=0 THEN P. "9: NON-ENTHALPY Mode"
1041    PRINT : INPUT "Enter Number above value to change (0 to exit): ",A
1042    IF (A<0) .OR. (A>10) THEN 1041
1050    ON A GOTO 1950, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900
1100    INPUT "Enter NEW Minimum Temperature (40-70):",A
1110    IF (A<40) .OR. (A>70) THEN 1100 ELSE Tmin = A : GOTO 1940
1200    INPUT "Enter NEW Maximum Temperature (60-90):",A
1210    IF (A<60) .OR. (A>90) THEN 1200 ELSE Tmax = A : GOTO 1940
1300    INPUT "Enter NEW Minimum Relative Humidity (30-50):",A
1310    IF (A<30) .OR. (A>50) THEN 1300 ELSE RHmin = A : GOTO 1940
1400    INPUT "Enter NEW Maximum Relative Humidity (40-60):",A
1410    IF (A<40) .OR. (A>60) THEN 1400 ELSE RHmax = A : GOTO 1940
1500    INPUT "Enter TEST Inside Temperature (35-100):",Tin
1510    IF (Tin<35) .OR. (Tin>100) THEN 1500 ELSE 1930
1600    INPUT "Enter TEST Inside Humidity (0-100):",RHin
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1610    IF (RHin<0) .OR. (RHin>100) THEN 1600 ELSE 1930
1700    INPUT "Enter TEST Outside Temperature (-30-130):",TX
1710    IF (TX<-30) .OR. (TX>130) THEN 1700 ELSE 1930
1800    INPUT "Enter TEST Outside Humidity (0-100):",RHout
1810    IF (RHout<0) .OR. (RHout>100) THEN 1800 ELSE 1930
1900    INPUT "Enter (1) for ENTHALPY, (0) for NON-ENTHALPY Mode:",ENTHALPY
1910    IF (ENTHALPY<0) .OR. (ENTHALPY>1) THEN 1900 ELSE 1930
1930    TEST=1 : PRINT "Temporary Test values in place."
1940    PRINT "Processing new values..." : GOSUB 720
1945    GOTO 1010
1950    A = GET
1960    PRINT
1965    IF TEST=1 THEN P. "Test input values rest to actual inputs."
1970    PRINT "Returning to internal control until next console input."
1975    GOSUB 700
1980    PRINT "Console/Laptop may be disconnected now...",CHR$(7)
1999    RETURN
2000    REM Read Channels 1-4 Subroutine
2005    Tin = 0 : Tx = 0 : RHin = 0 : RHout = 0
2006    SAMP = 10
2007    ADC = 0FF00H
2010    FOR X = 1 TO SAMP
2020    FOR C=9 TO 0CH
2030    XBY(ADC)=C
2035    B=(5*XBY(ADC)/255)-0.8
2036    IF C=9   THEN Tin = Tin + (B*15.625) + 40  : PORT1=254
2037    IF C=0AH THEN RHin= RHin + (B*31.25)       : PORT1=253
2038    IF C=0BH THEN Tx = Tx + (B*50.00) - 30     : PORT1=251
2039    IF C=0CH THEN RHout= RHout + (B*31.25)     : PORT1=247
2050    NEXT C
2052    PORT1=255
2060    NEXT X
2070    Tin=Tin/SAMP : RHin=RHin/SAMP : Tx=Tx/SAMP : RHout=RHout/SAMP
2099    RETURN
3000    REM RHth = f(RHout,Tx,Tin) for Enthalpy Control
3010    TEMP=Tx+459.67
3020    GOSUB 3100
3030    PWSO = PWS
3040    TEMP=Tin+459.67
3050    GOSUB 3100
3060    PWSI = PWS
3070    RHth = RHout * PWSO / PWSI
3099    RETURN
3100    REM ** CALC "PWS" FROM "TEMP" (RANKINE) **
3105    TERM = (-10440.397/TEMP) - 11.294465 + (-0.027022355 * TEMP)
3110    TERM = TERM + (1.289036E-5 * TEMP**2) + (-2.4780681E-9 * TEMP**3)
3130    TERM = TERM + (6.5459673 * LOG(TEMP))
3140    PWS = EXP(TERM)
3199    RETURN
4000    REM PROCESS CONTROL
4100    HEAT=0 : FAN=0 : OAir=0 : ALARM=0
4110    IF (ENTHALPY=1) THEN RHx = RHth ELSE RHx = RHout
4510    IF (RHin > RHmax) THEN HEAT = 1
4515    IF (Tin > Tmax)   THEN HEAT = 0
4520    IF (Tin > Tmax)    THEN IF ((Tin - Tx) > 3)   THEN OAir = 1
4522    IF (RHin > RHmax) THEN IF ((RHin - RHx) > 3) THEN OAir = 1
4524    IF (RHin < RHmin) THEN IF ((RHx - RHin) > 3) THEN OAir = 1
4526    IF (RHx > RHmax)  THEN OAir = 0
4550    IF (RHin > RHmax)  THEN FAN = 1
```

```
4552    IF (Tin > Tmax)     THEN FAN = 1
4560    IF (Tin < Tmin) THEN HEAT = 1 : OAir = 0
4564    IF (OAir=1) THEN FAN = 1
4565    IF (HEAT=1) THEN FAN = 1
4570    IF (Tin < (Tmin-5)) THEN ALARM=1
4580    CTRL3 = 255 : CTRL1 = 255
4582    IF (1=FAN)    THEN CTRL3 = CTRL3 - 4
4584    IF (1=OAir)   THEN CTRL3 = CTRL3 - 16
4586    IF (1=HEAT )  THEN CTRL3 = CTRL3 - 32
4588    IF (1=ALARM) THEN CTRL1 = CTRL1 - 128
4999    RETURN
5000    REM Read the RTC
5010    GOTO 5600
5020    BYTE=XBY(0FED0H)
5030    BYTE=(BYTE.AND.0EH)+1
5040    XBY(0FED0H)=BYTE
5050    BYTE=XBY(0FED0H)
5060    IF (BYTE.AND.2)=0 THEN  RETURN
5070    XBY(0FED0H)=(BYTE.AND.0EH)
5080    GOTO 5020
5100    BYTE=XBY(0FED0H).AND.0EH
5110    XBY(0FED0H)=BYTE
5120    RETURN
5600    GOSUB 5020
5620    FOR X=0 TO 0CH
5630    LET D=0FE00H+X*(10H)  : LET A(X+1)=XBY(D)-0F0H
5650    NEXT X
5660    GOSUB 5100
5900    RETURN
6000    REM Print the RTC Data from A(20)
6670    LET C=0
6680    PRINT "The DATE & TIME is:  ",
6690    IF A(0DH)=0 PRINT "SUNDAY, ",
6700    IF A(0DH)=1 PRINT "MONDAY, ",
6710    IF A(0DH)=2 PRINT "TUESDAY, ",
6720    IF A(0DH)=3 PRINT "WEDNESDAY, ",
6730    IF A(0DH)=4 PRINT "THURSDAY, ",
6740    IF A(0DH)=5 PRINT "FRIDAY, ",
6750    IF A(0DH)=6 PRINT "SATURDAY, ",
6760    IF A(0AH)=0 LET C=1
6770    FOR T=C TO 3
6780    PRINT CHR$(A(0AH-T)+30H),
6790    IF (0AH-T)=9 PRINT "/",
6800    IF (0AH-T)=7 PRINT "/",
6810    NEXT T
6820    LET C=0 :  LET V=0
6830    PRINT CHR$(A(0CH)+30H),
6840    PRINT CHR$(A(0BH)+30H),
6850    PRINT "  &  ",
6860    IF A(6)>1 THEN LET C=1 : LET A(6)=A(6)-4
6870    IF A(6)=0 LET V=1
6880    FOR G=V TO 5
6890    PRINT CHR$(A(6-G)+30H),
6900    IF (6-G)=5 PRINT ":",
6910    IF (6-G)=3 PRINT ":",
6920    NEXT G
6930    IF C=1 PRINT " P.M." ELSE PRINT " A.M."
6940    RETURN
10000   REM ERROR END
```

```
10050   CTRL1=255
10060   CTRL1=CTRL1 - 64  : REM Error End Light @ P1.6
10060   CTRL1=CTRL1 - 128 : REM Ring Alarm Buzzer @ P1.7
10070   PORT1=CTRL1
10100   END
```